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Nine meta-functions for science museums and science centres

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Abstract. Science centres and science museums face challenges such as increased accountability, increased demands for accessibility, and growing competition from leisure experiences. On their own, the traditional museum practices of preservation, communication, and research are insufficient to address these challenges. Accordingly, we use the framework of eight museum meta-functions, presented by Dubuc (2011) and further developed here, to understand how these institutions respond to calls for change. We analyse the presentations of staff members from 21 science centres and science museums, given at the 2013 Ecsite conference, to map out how these institutions address modern-day challenges. This analysis generates a new framework of nine meta-functions for science centres and science museums that can guide and help qualify discussions about their present and future activities. We discuss the new meta-functions as evidence of a turn away from the self-referential museum functions of the past, towards a more complete externalisation of purpose.

Introduction

Science centres and science museums are located within contemporary society with all its complexity. This puts them in a unique place to engage the public in relevant conversations (Welsh 2005), but at the same time, it also makes them subject to the forces of that ever-changing society (Hooper-Greenhill 2007). In order to endure, these institutions must respond to current-day challenges such as decreased funding, increased demands for accountability, increased demands for accessibility and diversification, and the growing competition from leisure experiences. These challenges require critical yet imaginative thinking throughout the institution.

We were offered an opportunity to witness this imaginative thinking first hand when attending the annual conference of the European Network of Science Centres and Museums (Ecsite) in 2013. As a professional, rather than an academic, conference it prioritises state of the art sessions and international perspectives. Thus, we expected the conference attendees to provide us with primary data by presenting their institutional state of the art and perspectives as 'direct evidence or first-hand testimony concerning a topic' (cf. University of Pittsburgh, 2016). We discuss this choice and its implications in more depth in the following; here, we limit ourselves to declaring that we chose three conference sessions that paid particular attention to this topic as our primary data for the following account.

The theme of the Ecsite 2013 conference was 'Dreams: The Spirit of Innovation'. According to the organisers of the Ecsite 2013 conference, the quest for a sustainable world requires a spirit of innovation. Further, they observe that in the on-going development of

science centres and museums, innovation has come to be seen as the responsibility of employees at all levels of the organization (Ecsite 2013). As a result of this focus, many of the conference speakers specifically addressed how they saw their institutions facing the challenges of the future, thus painting a picture of the practices and visions of present-day science museums and science centres from across the world.

In following, we pursue two goals: First, we provide a status report of the directions present-day science museums and science centres are headed, as well as their rationales for doing so. We believe this status report will be a timely contribution to both research and practice in these institutions. Second, from this report, we develop and present a framework for understanding and contextualising the functions of present-day science museums and science centres. We believe that such a framework can inspire and inform stakeholders in their continued efforts to meet external as well as internal challenges.

For the purpose of this study, we consider the institutions of science centres and science museums, respectively, to have converged towards forms with enough similarity that they are effectively members of the same group (Bandelli, Konijn, & Willems, 2009; Davis, 2010). Certainly, science centres and science museums (in the following: SCSMs) are subject to similar pressures to continuously legitimise themselves; in the present study, we assume they respond to this pressure in comparable ways.

The state of the art

What is the state of the art of science museums and science centres? Or in other words, what is the reference point we must take in order to discover new developments in their practices? In the 1980s, the Reinwardt Academie in Amsterdam created one of the best-known models of museum practice, which recognised three main functions: preservation, research, and communication (Desvallées, 2010). This model has been enormously influential, and is reflected in many contemporary policy documents.

The largest museum advocacy organisation is the International Council of Museums (ICOM) with 35 000 members worldwide. In its series of principles for desirable museum practice, (ICOM, 2006) outlines eight areas (Table 1), the first five of which seem to be directly related to the three functions of preservation, research, and communication. However, with the notion of 'collaboration with the community' (principle 6), ICOM reflects the emerging *nouvelle muséologie* described by Desvallées and Mairesse (2005), which is characterised by a stronger attention to the rights, needs, and local heritage of the individuals who live in the local area of the museum, rather than tourists and other transient visitor groups. Furthermore, a new focus on notions of museum management is apparent in principles 7 and 8, possibly as a response to the growing market economy faced by museums (cf. Mairesse & Desvallées, 2010; McPherson, 2006).

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Table 1. Indications of science museum/science centre principles and purposes, as stated in the policy documents of international advocacy organisations. Brackets indicate that the text refers to the advocacy organisation itself, rather than its constituent science museums and science centres.

Organisation	Principles/purposes
ICOM	1 Preservation, interpretation and promotion of the natural and cultural heritage of humanity
	2 Maintenance of collections for the benefit of society and its development
	3 The holding of primary evidence for establishing and furthering knowledge
	4 Provision of opportunities for the appreciation, understanding and management of the natural and cultural heritage
	5 Provision of opportunities for other public services and benefits
	6 Collaboration with the community
	7 Legal conduct
	8 Professional conduct
NATHIST	1 Build and store natural history collections
	2 Conduct research and interpret the results
	3 Support the process of science and biological conservation
	4 Enhance public understanding and appreciation of the natural world
	5 Collaborate with the public in deriving their own meaning from their natural heritage
CIMUSET	1 (To carry out a programme of activities related to the preservation of the cultural heritage within science and technology and dissemination of knowledge within this field)
	2 (Provide a forum for communication, co-operation and information exchange between museums, professional workers and others concerned with preservation of the cultural heritage within science and technology and dissemination of knowledge of this field)
Ecsite	(Our network strengthens citizen engagement and interaction with science, because science is an indelible part of culture, because citizens find empowerment with scientific knowledge and because experiential learning opens doors. These are the building blocks of participatory democracy in science, research and innovation – a fundamental component of a prosperous Europe)

A number of interest organisations address SCSMs more directly. The International Committee for Museums and Collections of Natural History (NATHIST) is a committee under ICOM that has defined a minimum standard of practice for natural history museums. NATHIST (2013) describes five principles for the 'multifaceted purpose of natural history museums' (Table 1). The first four of these principles seem to reflect the Reinwardt Academie model, albeit applied to a natural history context. However, principle 5:

'collaborate with the public in deriving their own meaning from their natural heritage' seems to reflect a turn away from museums being about something and towards their being for someone, described by Weil (1999, p. V). This turn acknowledges the evolution in museum representation from an object-based epistemology, in which museum objects were considered to speak for themselves, towards an object-based discourse, in which the main role of the object was its 'participation in the cultural or lived history of the visitor' (Evans, Mull, & Poling, 2002, p. 58).

The International Committee for Museums and Collections of Science and Technology (CIMUSET, another committee under ICOM) works to 'popularize and promote science and technology among children and young people all over the world' (CIMUSET, 2010). Unlike the organisations discussed in the preceding, CIMUSET does not prescribe standards for its constituent institutions. However, cautious extrapolation of the objectives CIMUSET sets for itself allows us to glimpse what it considers science and technology museums to be the proponents for: The preservation of cultural heritage within science and technology, and the dissemination of knowledge about cultural heritage within science and technology (Table 1, CIMUSET point 1). Again, we see an adherence to the Reinwardt Academie model in the organisation's focus on preservation and dissemination. It is interesting also to observe CIMUSET's emphasis on facilitating communication and co-operation between not just its constituent museums, but with other actors concerned with preserving and disseminating scientific and technological heritage (Table 1, CIMUSET point 2). The objective of enabling collaborations between (museum) institutions and actors with similar interests may indicate a desire to support the alliances, partnerships, and collaborations that have been increasing in number among non-profit organisations in recent years (Guo & Acar, 2005).

Like CIMUSET, the European Network of Science Centres and Museums (Ecsite), does not prescribe purposes for its constituents. However, it is apparent from the organisation's aims that it, like CIMUSET, values and promotes networking activities between its member institutions (Ecsite, 2012, see Table 1). Furthermore, we may extrapolate from Ecsite's statement of purpose that it sees SCSMs as proponents for the engagement of visitors with science with the ultimate goal of prosperity and informed citizenship. We thus observe an adherence to the communication function of the Reinwardt Academie model, albeit one that goes far beyond appreciating and understanding scientific heritage. The notion of empowering citizens is not a new one. Already in 2000, Henriksen and Frøyland pointed to a number of national museum policy documents that emphasised the potential democratic and civic functions of science museum communication (Henriksen & Frøyland, 2000). However, Ecsite is the only one of the four international advocacy organisations surveyed here that specifically emphasises the formation of scientifically literate citizens as an objective.

In summary, we surveyed the explicit and implicit statements of purpose for SCSMs in the policy documents of four international advocacy organisations. We found that these statements of purpose to varying extents reflected the Reinwardt Academie model of preservation, communication and research. In addition, we found a number of new emphases for SCSMs; collectively, these new emphases may be evidence of a shift towards a more complete externalization of purpose for these institutions. For instance, the focus on

management and legal functions may be a response to the need for SCSMs to reposition themselves in the marketplace (cf. McPherson, 2006), while the focus on collaboration and networking between institutions with overlapping interests could stem from the ambition to attract a larger segment of the general public (cf. Mairot, 1997). Finally, the increased focus on the visitor in the form of stronger ties to the local community, prioritising the viewpoints of the visitors over the 'language' of the object, and ultimately, attempting to create scientifically informed citizens, seems to be an indication of a broader tendency where institutions place their users and communities at the centre of their functions (cf. Black, 2012).

A forward-looking conceptual framework

Our survey of the policy documents of four international advocacy organisations demonstrates the continuing influence of the traditional and widely recognised museum functions formulated by the Reinwardt Academie. At the same time, the survey suggests that these traditional functions no longer encompass the full range of actions envisioned or undertaken by present-day institutions. Although we do not claim that our brief survey generated an exhaustive list of new or emerging SCSM functions, it does suggest the need for a more complete framework of functions that we can use as a reference point for our further study. The framework of museum meta-functions, developed by Dubuc (2011), constitutes an ambitious proposal for such a framework.

Developed with respect to museums in general and based on the Reinwardt Academie model, Dubuc's framework is an attempt to give a comprehensive description of present-day and future museum practice. She thus formulates eight museum meta-functions, namely the conservational, cultural, social, economic, scientific, political, educational, and symbolic functions, in her attempt to capture present-day museum transformations, irrespective of their particular type. It is of particular interest to us how Dubuc's notions of the cultural, economic, and political functions of museums align well with the SCSM functions that emerged in our survey. In the following sections, we first outline our data collection method and then show how we use Dubuc's framework, adapted to SCSMs, to find evidence for the eight meta-functions in the practices and visions of a number of institutions from all over the world.

Procedure

Data sources

The data sources for the present account are presentations made by SCSM staff members from three sessions at the annual conference of Ecsite – the European Network of Science Centres and Museums. The conference was held on June 6-8, 2013 in Gothenburg, Sweden, and had 1 058 participants (Schweingruber, 2013). The programme featured 88 sessions organised in eight parallel strands, and the majority of the speakers were SCSM staff members from various organisational levels of their respective institutions (Ecsite, 2013).

The decision to collect the data for the present study was made at the conference, and because only one of the authors attended the conference, it was possible to include a maximum of eleven sessions in the data collection. For each of these eleven time slots, the first author used the following criteria to select the session to attend:

- The theme of the session was related to SCSM practice in the present and future (this assessment was based on the 200-word abstract in the programme)
- The speakers were staff members from SCSMs (rather than researchers or private contractors)
- The session format prioritised presentation, rather than open discussion (priority was thus given to panel sessions, reverse panel sessions, and pecha kucha sessions rather than e.g. workshops and science café formats)

The parallel structure of the conference meant that several sessions that could have been relevant could not be included. We thus ended with a relatively small sample of three sessions that fulfilled the criteria and were accessible for data collection:

1. After Exploratorium: The shifting identities of science centres
2. Do science centres need objects?
3. Content re-development: An academic science museum and the freedom to innovate

The duration of the sessions was 75-90 minutes, and they featured from 2 to 16 speakers. The first author attended all three sessions, taking notes and audio recording the presentations. After obtaining the permission of the speakers, the recordings were transcribed verbatim and forwarded to the speakers for clarification. The affiliations of the speakers are listed in Table 2; in the following they are referred to by type of institution and country.

Data Analysis

The transcriptions of the three sessions were analysed using *theoretical thematic analysis* (Braun and Clarke, 2006). The aim was to identify instances of the eight museum meta-functions in the discourse of SCSM staff members, and to capture any additional functions present in the data but not included in the original framework. We followed the six-step analytical tool (cf. Braun and Clarke 2006) described in the following.

In the first step, the transcriptions were carefully read and re-read. In the second step, the utterances of the staff members were subdivided into groups corresponding to the eight meta-functions of museums. In this process, we came across several instances of utterances with more than one theme; in such cases, we determined what was foreground and what was background, and sorted by foreground. An additional, ninth meta-function emerged in this phase.

In the third step of the analysis, the categorization of each utterance was either confirmed or altered, and emergent subthemes were noted. This process was repeated until stable subthemes were established, and confirmed the existence of subthemes pertaining to the additional, ninth meta-function. In the fourth step, the nine themes and the subthemes were refined, and it was ascertained that there was enough coherent data to support each of

them in a meaningful way. In the fifth step, the themes and subthemes were organised into internally consistent accounts, described by an accompanying narrative. Finally, in the sixth step, the analysis was written up for the present text.

Table 2. Affiliations of the conference speakers included in the present analysis. 15 countries are represented by the 21 speakers.

Type of institution	Country	Session
Science centre	Denmark	1
Science centre	France	1, 2
Science centre	Germany	1
Science centre	Japan	1
Science centre	Switzerland	1
Science centre	Sweden	1
Science centre I	UK	1
Science centre II	UK	1
Science centre III	UK	3
Science centre	USA	1
Independent Consultant	USA	1
Museum	Brazil	1
Museum	Hong Kong	1
Museum I	Italy	1
Museum II	Italy	1
Museum	The Netherlands	1, 2
Museum	Russia	3
Museum	Spain	1
Museum I	UK	3
Museum II	UK	3
Museum	USA	1

The conference as study site

The use of a professional conference as a study site warrants some consideration. In the humanities, a primary data source is 'something that was created either during the time period being studied, or afterwards, by individuals reflecting on their involvement in the events of that time' (University of Pittsburgh, 2016). This description conceivably encompasses presentations carried out by SCSM professionals to describe their understanding of the current of affairs at their respective institutions. In the natural sciences, primary data sources include 'reports of original research or discoveries (e.g., conference papers [...])' (University of Pittsburgh, 2016). Accordingly, we consider the presentations given by SCSM

professionals to be evidence of their understandings, reflections and intentions at the given point in time.

One might object that conference presentations do not reflect reality, but are idealised accounts that gloss over inconsistencies or inconvenient facts. Indeed, we have no way of knowing to what extent this is the case here. In the following, we have chosen to take the utterances of the staff members at face value.

Analysis and Discussion

Our analysis confirmed that all of the eight meta-functions of Dubuc (2011) were present in the discourse of the staff members. Furthermore, we found evidence of an additional ninth meta-function, namely the *network* function. Each meta-function was present in the discourse of staff members from at least four different institutions, suggesting that these functions indeed do describe shared elements of current and future practices of SCSMs. In addition to identifying these nine meta-functions, we also identified a number of subthemes (Figure 1). In the following, the nine meta-functions are reported and discussed in order of their prevalence across the data set.

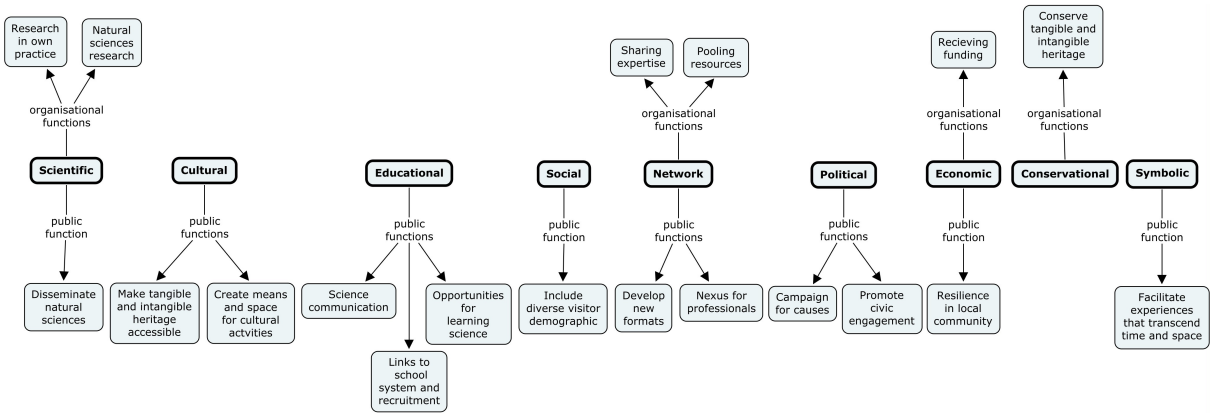

Figure 1. The nine meta-functions identified in the present study, along with their externally oriented (public) and internally oriented (organisational) subthemes.

The scientific function

In their discussions of the scientific meta-function, staff members referred to scientific functions with both an internal, organisational focus (natural sciences research as well as research into the institution's own practice) and an external, public focus (the dissemination of science).

Natural sciences research

Historically, the scientific function of museums was connected to their role as research institutions (Dubuc 2011). Today, this function has been scaled back in many museums as the scientific disciplines have become detached from these institutions and increasingly associated with universities (Conn 2010). Science centres, on the other hand, have not

traditionally been places of natural science research, but have relied on other institutions to generate the science they disseminated (cf. Oppenheimer 1968). Perhaps this distance between the production of science on one hand, and SCSMs on the other, explains why staff members from just two institutions discussed their institutions' science research function. It may also explain why, in both cases, staff members mainly problematized the relationship between the science going on 'behind the scenes' and the science that was disseminated to the public, rather than discussing scientific products or processes themselves:

> [Our museum] has about 350 research scientists, and a collection of 71 million objects, which are used for active research. It's one of the largest science research organizations in the world. But it was completely and utterly invisible, back in 2001. So the challenge was how to make this kind of activity [refers to slide with laboratory work] visible and open to the public in some way (Museum II, UK).

Neither of the two staff members saw natural science research as the *raison d'être* of their institution. This is perhaps not surprising given that none of the staff members that contributed to this study were scientific staff *per se*; however it may indicate that the role of natural science research in itself is gradually becoming less important to SCSMs, as compared to how science can be used as a way to connect with the public.

Research in the institution's own practice

A more recent facet of the scientific function of SCSMs is the development of new fields of research directed towards the institutions' own practice, i.e. related to the relationship between the public and the institution (Dubuc 2011). In an attempt to better understand their publics, a number of institutions have in recent years established research departments tasked with improving their dissemination efforts (Hein 1998). We found evidence of such efforts in the discourse of three staff members. In two cases, the staff members simply stated that research into their own practice was a key part of their work, while in the third case, the staff member described how questioning the institution's own dissemination efforts had led to a more profound line of inquiry, undertaken in partnership with a local university:

> We also discovered that we all think that we know what dialogue is. And we don't. Dialogue wasn't happening. What we had was telling, and we had a few questions. Now, Q&A feels like a dialogue, but actually, it isn't. And we started working with academics at [University] to study what dialogue really means and how we can foster it (Museum II, UK).

This quote further illustrates an important tendency in the data, namely that network approaches and collaboration across institutions are becoming increasingly important to SCSMs. We will return to this point in the section about the network function.

The dissemination of natural sciences

The external face of the scientific function of SCSM is the advancement of natural science knowledge among their publics (Dubuc 2011). Dissemination of science was by far the most frequently invoked subtheme of the scientific function. In this context, many discussions

addressed the particular *perception* of science disseminated by the institutions. These perceptions ranged from somewhat idealised and absolute views to more critical and contextualised understandings. The more idealised end of the range is exemplified by the following statement:

> Take science seriously. I mean science in the broad sense. It's your theme; whether you do physics or geography or language or history, take your theme seriously. This is the basis we are building on, and as a consequence […] we try to lead the visitors as quickly and directly as possible to the scientific phenomena. So we do not want visitors to get distracted, but [rather] concentrated on the things. And so […] we try to show the exhibits in the most direct and honest way (Science centre, Germany).

However, recent discussions in the research literature have problematized the dissemination of science as monolithic, straightforward, and politically safe, calling for more nuanced and critical perspectives (Pedretti 2002). And this call seems to be increasingly perceived by SCSMs, as exemplified here:

> We have had some interesting lectures at the science centre about controversial issues. There is a gene in our DNA called the 'evil gene'. And if you have that gene, then you are more willing to fight, and more willing to beat your wife and so on. And a company in Denmark […] has made a study of whether you can remove the 'evil gene'. Then we had a debate at the [science centre], and there was a pro and con about: Should we allow that to happen? (Science centre, Denmark).

Some staff members were even more explicit in considering science as a socio-historically established construction, and in thinking about how to disseminate this more nuanced and human view of science to their publics. For example, one staff member explained how they attempted to capture, in an exhibition, the 'the drama of the discovery of the Higgs light particle' (Museum I, UK). This line of thought resonates with recent suggestions that initiatives to promote public engagement should go beyond science as a reasoned argument to mobilise the non-discursive aspects of science such as its affective and embodied aspects (Davies, 2014).

If we consider the scientific meta-function to be a development of the traditional, Reinwardt Academie research function, the subthemes on research in own practice and dissemination of science represent a turn towards a new, more externally oriented face of this function. On the basis of our analysis, we would thus define the scientific meta-function of SCSMs as their endeavours to advance knowledge, both by conducting natural science research and research into their own practices, and by disseminating knowledge of natural science.

The cultural function

The *cultural function* of museums is twofold: in one sense, the museum is considered a cultural actor, and in the other sense, a cultural resource for the community (Dubuc 2011). We found instances of both elements in the discussions of staff members.

The institution as a cultural actor

In its more traditional role as a cultural actor, the museum makes material objects, natural specimens, and intangible heritage accessible to the public (ICOM 2006). In a science context, this implies an emphasis on the fact that science is part of our cultural heritage (cf. Osborne and Dillon 2008). Staff members from several institutions invoked this subtheme in their discourse, stating how they saw science to be an inextricable part of human culture, e.g. 'I don't think that science is something different than culture. […] Science *is* culture' (Museum, The Netherlands).

In terms of making this culture accessible to the public, staff members from several institutions discussed how to adapt their content to their local context and audience, as illustrated in the following example:

> I think there are lot of science centres around the world, and […] I think it was sad to see that sometimes, every science centre had exactly the same exhibits in the centre. So I really think we need to develop more context, more personality (Museum, Brazil).

This staff member is lamenting the phenomenon of 'cloning', which has had the effect of creating multiple copies of the same exhibits in science centres across the world (Quin, 1994). Cloned exhibits obviously fail to incorporate the local cultural contexts that could help resident visitors access and make meaning of the scientific heritage on display. There seems to be a desire, among staff members, to be sensitive to and represent such localised interpretations of scientific culture (cf. Pedretti, 2002).

The institution as a cultural resource

In its role as a cultural *resource*, the museum goes beyond traditional object-centeredness, becoming a means to participate in and express culture (Dubuc 2011). In this role, the museum's activities typically become more participation-driven than curator-driven, broadening the notion of authority (Simon 2011) and ideally becoming a community resource for the creation and development of cultural identity among visitors (Carnall et al. 2013). This subtheme was expressed in a variety of ways among staff members, for example:

> Our publics want to participate; they want to be part of the game; they want to say their word on the things we do (Museum II, Italy).

> There's been a lot of debate about [the] maker visitor trend: Is it a fad? I don't know. I don't really care, to be honest. I just know that it is a very, very good fit for the [science centre]. We're a gritty, working city, which had a very, very proud past in making things, and so it hits the nostalgia buttons. It hits people in the heart, which is great, it's relevant to them; and it's very relevant moving forward. People want to make things (Science centre II, UK).

These excerpts, as well as the further discussions among staff members, could be evidence of an increased resolve to allow subjective, local voices a place in the activities of the institutions (cf. Pedretti 2002). Taken together, the discussions of the staff members about their institutions' roles as cultural actors and resources seem to indicate a turn towards a more

inclusive notion of scientific heritage; one that allows (or even requires) the participation of the visitors. Thus, our definition of the cultural meta-function of SCSMs is the provision of opportunities for the public to engage with, participate in, and express their shared scientific heritage in ways that are culturally meaningful to them.

The educational function

The *educational function* has historically been more widely acknowledged as a core objective of the science centre movement than as an explicit goal of many science museums (Koster 1999). However, the relationship between the public and science museums is evolving (Hooper-Greenhill 2007), and as a result, many of these institutions are exploring new ways of engaging their visitors to promote learning (Welsh 2005). We found several subthemes of the educational function in the discourse of staff members, namely science communication and links to formal education, including the notion of recruitment, i.e. the ways in which SCSMs can generate interest and motivation for science-related study and career paths. The intention to positively affect recruitment is exemplified in the following:

> Our greatest challenge, for me, is how we reach the people with low aspirations, low expectations, and get them drawn into the amazing world of science and careers and so on. That's the big challenge for us (Science centre I, UK).

However, the main part of the discourse about the educational meta-function seemed to revolve around SCSMs as providing learning experiences for non-school publics. One staff member emphasised how their institution engages visitors in the methods of science to pursue their own inquiries in a 'laboratory space; a space where visitors are investigating authentic phenomena' (Science centre, USA). Another staff member invoked their institution's ability to promote excitement and interest in the natural and physical world:

> And this is our mission statement [emphasises slide text: 'Captivate the public's interest, curiosity and imagination through interactive exhibits'], similar to many science centres over the world. In short, we aim at promoting the public's interest in science and technology (Museum, Hong Kong).

Based on the preceding, we define the educational function of SCSMs as encompassing activities that attempt to engage visitors in science with the intention of achieving specific educational outcomes, ranging from developing scientific skills and knowledge to more affective outcomes such as promoting long term interest in science. Whilst the communication function outlined by the Reinwardt Academie refers to the presentation of results and the provision of information (Desvallées & Mairesse, 2010), the new educational meta-function seems based on a more nuanced view of learning as the participation in, or acquisition of, science. Based on the discussions of the staff members, this participation or acquisition can be cognitive, affective or even procedural in nature. To the extent that the educational meta-function can be considered a development of the traditional communication function, it has evolved from a more narrow, transmission-absorption conception of education to a much richer, constructivist understanding.

The social function

The *social function* of the SCSM refers to its value to society. Although historically, museums have tended to exclude various minority groups in society through mechanisms such as the use of culturally specific exhibitions and activities (Dawson 2014) or selective advertising (Sandell 1998), today social inclusion is becoming a stated priority for many SCSMs (McPherson 2006). Indeed, in the present case, staff members' discussions touched upon the challenges of providing inclusive experiences for all demographics as well as the successes of already-implemented, socially inclusive activities. An example of the former discussion is given in the following examples:

> The hardest audience to reach are poor people. There are different ways of referring politely to them, but 'disadvantaged people' is what we call them in the UK. And science centres often appeal to well-off, middle class parents who are already motivating their kids (Science centre I, UK).

In addition to the low-income communities addressed in this statement, other underserved demographics were also mentioned by staff members, e.g. the elderly, people with sensory impairments, and people with lower levels of educational attainment. An interesting example of an initiative that had proven successful at attracting diverse publics is given in the following:

> Our last Maker Fair attracted… seventy per cent of the people who came had never been to the Centre before, which I found to be an absolutely staggering statistic. So, I think we're moving in the right direction (Science centre II, UK).

Other staff members described the ways in which their institutions had reached new audiences through approaches such as partnerships with other institutions, community outreach initiatives, and new participatory activities such as maker spaces. Ideally, all of society, minorities or marginalised groups as well as more advantaged members, would use the museum as a vector for social awareness, development, and change (Dubuc 2011). The focus of the staff members on this aspect of the museum's functions is evidence that they share this concern.

In this context we define the social function of SCSMs to relate to all efforts made to appeal to and include potential visitors from groups otherwise excluded due to physical, cultural, financial or other circumstances. This function resonates with the *nouvelle muséologie* movement mentioned earlier, which involves prioritising the local community and addressing their particular needs and requirements, rather than attempting to cater to tourists.

The network function

The *network function* represents a relatively new direction for SCSMs. Not included as one of Dubuc's (2011) original eight meta-functions, we use the network function to refer to within-sector and cross-sector collaborations that include SCSMs among other institutions to achieve shared goals through collaborative efforts, pooled resources, and joint decision making (cf. Guo and Acar 2005). Staff members referred to network functions with both an institutional

focus (pooling resources and sharing expertise) and a public focus (developing new formats and providing a professional nexus).

Pooling resources, sharing costs

The present-day climate of financial uncertainty experienced by SCSMs (Lindqvist 2012) may be their most fundamental reason for forming networks. Networks allow for the sharing of costs and the pooling of resources to the benefit of all, as indicated in the following statement:

> And by network, I mean […] exchange, and not exchanging because you want to be nice in exchange: exchanging out of necessity. So I have something, you have something, you have something, and it will rotate through the three places. And therefore I have to talk to you. […] For me, the future of science centres is really in that direction (Science centre, France).

Sharing expertise

Lowering expenses was not the only rationale given by staff members for the formation of collaborations across institutions. Perhaps as a result of the gradual detachment of natural sciences research from museums discussed earlier, scientific expertise is no longer as readily available here. For science centres, on the other hand, natural science research was never a central part of institutional practice. In either case, drawing on the expertise of other institutions may be a way to ensure the continued integrity of the institution. For instance, one staff member discussed how their institution was lacking expertise in a key area of an exhibition topic, and thus was 'really challenged to start speaking to people outside the organization' (Science centre III, UK).

Developing new formats

The public side of the networking meta-function is the creation of new formats for dissemination in public spaces. One staff member describes how their institution is attempting to reach out beyond its walls:

> We also look to extend ourselves geographically. We look for partnerships, interesting settings, and new audiences. On the far right (refers to slide), you actually see little exhibits that were created for a library in Queens, with an incredible diversity of audience. And they fit literally on the shelves, and they help demarcate different subject areas. So the idea of a classic phenomenological exhibit being in a library shelf is something that extends the core vision that we still believe in to a new location (Science centre, USA).

The idea, described by this staff member and others, of extending the institution beyond its street address is a necessity, according to Black (2012), if the institution wishes to identify ways in which it can be relevant and commit to the reflection of multiple perspectives. In this sense, the network function may contribute to addressing the cultural and social functions.

Nexus for professionals

Finally, collaborations across institutions may serve as a nexus or means of connection between professionals. Staff members discussed collaborations with industrial partners, universities and experts of city technology, engineering, and infrastructure. One staff member discussed their science centre's location in a 'science village' in the following way:

> So alongside these science educators are doctors, and nurses, and business people, and you come to the site not just to go to the science centre, you come to the site for an appointment with the doctor, you come for a clinic. So it's for me a friendly, welcoming face of science, and it's demystified science for the people. Something that is embedded in the everyday culture of the city. And it's been a fantastic experiment in interdisciplinary learning. Not just the educators, but [also] the scientists in the same building (Science centre II, UK).

In summary, the network meta-function seems to be an established practice among the institutions in our sample, with a variety of both internal and external purposes. Even though the ultimate driving force of networking may be necessity in the form of resource scarcity and increased competition for funding, there are a range of potential benefits to collaborating, such as increased legitimacy (Proulx, Hager, & Klein, 2014) and richer educational offerings for visitors (Mairot 1997). Accordingly, we would define the network meta-function of SCSMs as any inter-institutional collaboration, with an internal or public focus, that has the ultimate purpose of achieving shared institutional goals.

The political function

The museum's *political function* refers to the ways in which it influences political decisions, both directly and indirectly. A direct way of influencing policy is by campaigning for causes; staff members from three institutions discussed such campaigning in relation to their institutions. A more indirect way for SCSMs to be involved at a political level is by contributing to creating a strong collective identity among its publics (Dubuc 2011), thereby promoting civic and democratic engagement. Staff members from two institutions discussed this aspect of their political function.

Campaigning for causes

One museum staff member described an ambitious project that used their institution as a platform to effect reforms in science education legislation:

> Using the museum as a platform to do educational reform has worked wonderfully in a very complicated country like the United States. And I would like to encourage you to take science or engineering topics you would like to influence schools to include – and go for it, because you can be very effective (Museum, USA).

Another staff member disagreed with this approach, stating 'we shouldn't be campaigning organisations [...], we should keep to the principles of science' (Science centre I, UK). The question of whether or not SCSMs ought to directly influence policy and policy-makers is a relevant one. More and more, national policy documents are explicitly referring to non-school

science learning environments as important and requisite components in achieving national science standards (e.g. Danish Ministry of Education 2014; National Research Council 2012); it is perhaps not surprising that the non-school institutions respond in kind.

Promoting civic engagement

The role potentially played by museums in promoting a democratically informed citizenry seemed less controversial. One staff member spoke about how their institution was currently promoting civic engagement with respect to issues such as urbanization and climate change by sending 'a very clear message that [...] solutions were graspable, that they were available if all levels of society engaged with them' (Science centre III, UK). Another staff member had a sweeping vision for the future of SCSMs, seeing them as playing an all-important role for the generations to come:

> My opinion is that the future will be really different than before. […] Within this century, two more billion human beings will face the planet. That means four billions of new consumers in one century. […] New generations will have more and more trouble to govern and to make their lives meaningful. In this case, education will be a great part of our mission. And in this case, our science centres and scientific museums can have a great role in this education system – because we can help generations, new generations and ourselves, to have a mission in life; to face these new, enormous troubles (Museum I, Italy).

Many would agree that SCSMs contribute to building a collective identity among their publics (e.g. Hein 1998). However, as suggested by Koster (1999, 289) SCSMs may have an as yet unexploited potential to shape that collective identity into a strong democratic presence by empowering their publics to be 'active commentators on the science and technology issues surrounding them', and by sharing that discussion with media and government authorities. It seems these objectives have hitherto been difficult to embody in SCSM practices (Rennie & Williams, 2006). Even so, the objective of empowering visitors for modern democracy is not a new goal for science museums; certainly a number of national policy documents emphasise the democratic and civic functions of science museum communication (Henriksen & Frøyland, 2000). In summary, we would define the political function of SCSMs as the actions taken by such institutions to participate actively in or to encourage visitors to participate actively in dealing with socio-scientific issues.

The economic function

The *economic function* of the museum refers to the ways in which the institution generates revenue, but also to way it is financed (Dubuc 2011). Staff members from three institutions discussed the economic function; they considered both the internal fundraising aspects of their economy and the external, more public aspects of their economy.

Fundraising

Today, museums are becoming increasingly dependent on external financial support as public subsidies wane (Davidsson and Sørensen 2010), and may be approaching the level of dependency on private-sector contributions and sponsorships that has been a fact for most

science centres since their inception (Koster 1999). It is thus not surprising that staff members discussed fundraising.

Resilience for local community

An interesting economic discussion was centred on the ability of SCSMs to provide momentum and resilience to their local communities. One staff member described how their institution was founded as part of a larger organization consisting of three pillars, to provide strength and flexibility to the local community:

> [The organisation] was founded in the nineties, when Sweden went through an economic crisis like many countries in Europe are today. [The organisation] was created as a triple helix to help [city] survive and transform if the industry would fail. And one and a half year ago, [major company] went bankrupt. [The organisation] has three tools to improve the society. One incubator for new enterprises, one platform for R&D, and a science centre (Science centre, Sweden).

Two opposite forces may be at play: Due to their internally oriented fundraising efforts, many SCSMs are considered indirect generators of income (McPherson 2006) because they attract funding to the local area. Indeed, museums do have the potential for providing return on investment to their local communities, in terms of employment and increased revenue - the 'Bilbao effect' (Plaza 2007). However, if the impetus to attract this funding is the tourist industry, these institutions may inadvertently end up neglecting their local communities (Dubuc 2011).

SCSMs may be experiencing a market economy in which their *raison d'être* is increasingly determined by demand, rather than more idealistic notions of public benefit. These changed circumstances could be precipitating a change in the institutional attitude of SCSMs: From considering money as incidental to their core activities to considering financing and revenue as *de facto* institutional purposes which necessitate corresponding adjustments in management strategies. We thus define the economic function of SCSMs as the activities of these institutions to strategically seek funding and generate revenue in an increasingly market-based economy.

The conservational function

The *conservational function* refers to the task of conserving vestiges of the past. While material objects and artefacts have historically been the focus of museum collections, Dubuc (2011) suggests that the scope of conservation efforts be broadened to encompass immaterial culture and intangible heritage. Immaterial and intangible heritage arguably includes cultural and scientific practices and usages (Welsh 2005), and thus has considerable overlap with those respective meta-functions. Therefore, we focus on material heritage in this category of functions.

We observed a number of discussions about the conservational function of SCSMs. One staff member invoked the ability of material objects to create immaterial 'magical moments' (Museum, The Netherlands), thereby perhaps supporting the continued practice of

collecting and conserving material objects. Another asserted that the conservation of scientific heritage could not be dealt with purely through the display of material objects alone:

> So whilst we will draw on our own collections to tell the history of particle physics, and on our collaboration with CERN to feature real objects from the Large Hadron Collider, this is definitely not a topic that we felt could be tackled through object display alone (Museum I, UK).

For these staff members, there seemed to be a strong sense that conserving scientific heritage is not just a matter of collecting objects and practices for the sake of collecting, but that the mobilization of those collections into interpretative activities is their *raison d'être*. One staff member stated:

> We need to change storing for communicating; we need to change the old model of the museum: that the museum is a place for storing objects, for researching objects and present specific knowledge; to communicate. We need to change the object - to transform the object into a message (Museum, Russia).

It seems that in the coming years, we may witness a shift in focus for museums, away from collecting objects for their own sake towards collecting them for the scientific and cultural practices that give them meaning. In this way the conservational function can be seen as a distinctive function related to the principles behind the scientific and cultural functions. We therefore define the conservational function as the efforts of SCSMs to collect and preserve objects for the purpose of communicating significant scientific achievements, events or locations.

The symbolic function

The *symbolic function* is the ability of the institution to create a suspension of time and place, providing visitors with a space where they can express themselves symbolically (Dubuc 2011). We understand this to mean that SCSMs have the potential to offer their visitors new experiences beyond those constrained by buildings, geographical location, or ownership (Beetlestone, Johnson, Quin, and White 1998) such as the defining voyages in the history of humanity or the use of technical artefacts to explain the development of civilisation (Janousek 2000).

The symbolic function was present in the discussions of a number of the staff members. One staff member invoked a personal experience as an example of the symbolic function of SCSMs:

> This thing is the Apollo capsule (shows slide) that is in the science museum. This is really what made me feel how it was for the first astronauts to go in space, phew, just relying on all the calculations, just relying on the validity of science, and this object really, really, really impressed me (Museum, The Netherlands).

Another referred to the 'big questions' of humanity:

> This [exhibition] will take our visitors inside what is arguably the world's greatest experiment: the Large Hadron Collider at CERN. Now, as an exhibition topic, this is a fairly challenging one. It encompasses not only the enormous questions that we and those scientists are asking about the nature of the universe, [the] epic engineering of the Collider and its tunnels, [but also], at the other end of the scale, the subatomic and the frankly fairly mind-bending physics that's happening there (Museum I, UK).

To these staff members, SCSMs offer unique, sensory experiences through their concentrated reality. A tendency among SCSMs seems to be an increased focus on sensory experiences, e.g. as exemplified by the emergence of immersive exhibits (cf. Author 2010). It is interesting to note that although stimulating the imagination of visitors – allowing them to think of things 'possibly being so' – has rarely been explicitly stated as an objective of SCSMs, it is arguably a strong component of the experience and should perhaps be explicitly addressed (Author 2016). We define the symbolic meta-function of SCSMs as the (often tacit) purpose of facilitating science-related experiences that cause visitors to mentally transcend the time and place of their visit.

Limitations

Before we discuss the implications of our findings, we address an important limitation of the present study. The data used to construct the present narrative are a convenience sample, i.e. they were drawn from the part of the population of SCSM staff members that was close at hand due to the Ecsite conference. The conference hosted staff members from SCSMs from 47 countries; even so, we cannot claim to have randomly sampled the population, nor can we claim that our results are generaliseable across the domain of SCSMs. The definitions of the meta-functions that emerged from our data analysis, combined with Dubuc's (2011) original proposal, should therefore be considered tentative, as should the list of nine meta-functions itself.

On the other hand, the nine themes that emerged from the analysis were quite consistent across institutions. This suggests that among the sampled institutions, there is a high degree of convergence towards similar solutions to the problem of innovating for the future. Certainly, there are contemporary SCSM innovations that were not discussed by the staff members, for instance the numerous citizen science initiatives (e.g. Ballard et al., in press); other newer practices such as participatory design efforts were briefly touched upon by staff members (see e.g. the section *The institution as a cultural resource*) but are increasingly becoming a part of the established routines of SCSMs. However, we have attempted to define the meta-functions in a way that makes them specific to SCSMs (rather than museums in general), yet allows room for initiatives that did not emerge from our sample.

Implications

We have examined the state of the art of SCSMs, and in this process, experienced a glimpse of their visions for the future. This allowed us to identify nine meta-functions for SCSMs (Figure 1), and give these meta-functions tentative definitions. Three of these meta-functions

are based on the original three functions described by the Reinwardt Academie, namely preservation, communication, and research, but six of them are relatively recent additions. Although we cannot make claims to the ability of the nine meta-functions presented here to encompass the full variety of interests, practices, purposes, and strategic directions of institutions across the world, our study does give an indication that present-day SCSMs have a variety of interests and ambitions that are not circumscribed solely by the traditional functions. Even though some of the new directions taken by present-day SCSMs are present in the policy documents reviewed in the beginning of this text (e.g. building cultural identity or contributing to scientific literacy), they are not consistently and explicitly present across the surveyed policy documents. We thus believe the nine museum meta-functions, based on the work of Dubuc (2011) and expanded, adapted and validated here, constitute a framework for understanding the present and future directions of SCSMs and similar institutions.

Although our sampling is limited and, to some extent opportunistic, our findings may be an indication of a significant shift in focus, away from self-referential museum functions that are rapidly becoming out-dated, and towards a more complete externalization of purpose. Certainly, it is noteworthy that the traditional museum functions discussed at Ecsite 2013 show signs of having been re-appropriated to reflect a more community-oriented perspective. Indeed, we observed how the traditional *preservation* function seems to have been subsumed by the notion of conservation - not for the sake of maintaining collections, but for the sake of bringing specimens, artefacts, and practices to life for the public through cultural or scientific functions. Further, the shift in definition of the traditional function of *communication* towards the more all-encompassing term education, with its subthemes of recruitment, learning, and links to the school system, seems to indicate a more inclusive approach. Finally, we saw how the traditional function of *research* has blossomed into a scientific meta-function with several subthemes, including that of conducting research to develop the science dissemination practices of the institution itself, thereby improving its ability to engage its audiences.

This shift in focus can be interpreted as part of a broader tendency where institutions place their users and communities at the centre of their functions. Black (2012) describes this as thinking *with,* as opposed to adopting an authoritative stance *towards,* the public and other external actors and institutions. In essence, thinking *with* involves establishing long-lasting relationships with users as well as partnerships with a wide variety of cultural or educational institutions, private companies, local communities, ethnic and social groups and other relevant agencies as our examples illustrate. Building a broad and involved user base as well as lasting partnerships seems to be a necessary route today as it has been for 20 years:

> Partnerships allow museums to extend the boundaries of what is possible: to share risks, acquire resources, reach new audiences, obtain complementary skills, improve the quality of service, achieve projects that would otherwise have been impossible, acquire validation from an external source, and win community and political support (Anderson 1997, 69 as quoted in Black 2012, 11).

In this perspective, it is interesting to note that our addition of the network meta-function to the eight original meta-functions underpins the increased focus on connecting SCSMs with other institutions, people and communities. Although we found many mentions of

collaboration, partnerships, outreach and other forms of relationships in our data, we believe we have only just scratched the surface of understanding the potential of institutional networks. We hope that future research will be devoted to exploring their nature.

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References

Alberch, P. 1994. "The Identity Crisis of Natural History Museums at the End of the Twentieth Century." In *Towards the Museum of the Future*, edited by R. Miles and L. Zavala, 193-198. London: Routledge.

Ballard, Heidi L., Lucy D. Robinson, Alison N. Young, Gregory B. Pauly, Lila M. Higgins, Rebecca F. Johnson, and John C. Tweddle. In press. "Contributions to Conservation Outcomes by Natural History Museum-Led Citizen Science: Examining Evidence and Next Steps." *Biological Conservation*.

Bandelli, Andrea, Elly A. Konijn, and Jaap W. Willems. 2009. "The Need for Public Participation in the Governance of Science Centers." *Museum Management and Curatorship* 24 (2):89-104.

Bedford, L. 2004. "Working in the Subjunctive Mood: Imagination and Museums." *Curator: The Museum Journal* 47 (1):5-11.

Beetlestone, J. G., C. H. Johnson, M. Quin, and H. White. 1998. "The Science Center Movement: Contexts, Practice, Next Challenges." *Public Understanding of Science* 7:5-26.

Black, G. 2012. *Transforming Museums in the Twenty-First Century*. London: Routledge.

Braun, V., and V. Clarke. 2006. "Using Thematic Analysis in Psychology." *Qualitative Research in Psychology* 3 (2):77-101.

Carnall, M., J. Ashby, and C. Ross. 2013. "Natural History Museums as Provocateurs for Dialogue and Debate." *Museum Management and Curatorship* 28 (1): 55-71.

CIMUSET. 2010. "The International Committee for Museums and Collections of Science and Technology: Our Aims." ICOM, accessed December 11, 2014. http://network.icom.museum/cimuset/about-us/our-aims/

Conn, S. 2010. *Do Museums Still Need Objects?* Philadelphia: University of Pennsylvania Press.

Davidsson, E., and H. Sørensen. 2010. "Sponsorship and Exhibitions at Nordic Science Centres and Museums." *Museum Management and Curatorship* 25 (4): 345-360.

Davies, Sarah R. 2014. "Knowing and Loving: Public Engagement Beyond Discourse." *Science & Technology Studies* 28 (3): 90-110.

Davis, A. 2010. "Conclusion." In *What is a Museum?*, edited by A. Davis, F. Mairesse and A. Desvallées, 186-187. Munich: Verlag Dr. C. Müller-Straten.

Dawson, E. 2014. ""Not Designed for Us": How Informal Science Learning Environments Socially Exclude Low-Income, Minority Ethnic Groups." *Science Education* 98 (6): 981-1008.

Desvallées, A. and F. Mairesse. 2010. *Key Concepts of Museology*. Paris: Armand Colin.

Desvallées, A., and F. Mairesse. 2005. "Point de Vue sur la Muséologie. [A Perspective on Museology]." *Culture & Musées* 6: 131-155.

Dubuc, É. 2011. "Museum and University Mutations: The Relationship Between Museum Practices and Museum Studies in the Era of Interdisciplinarity, Professionalisation, Globalisation and New Technologies." *Museum Management and Curatorship* 26 (5): 497-508.

Ecsite. 2012. *Collaboration, Engagement, Impact*. Annual report, edited by Catherine Franche. Brussels: Ecsite.

Ecsite. 2013. *Dreams: The Spirit of Innovation*. Programme of the Ecsite Annual Conference 2013 Gothenburg. Gothenburg: Universeum.

Evans, E. M., M. S. Mull, and D. A. Poling. 2002. "The Authentic Object? A Child's-Eye View." In *Perspectives on Object-Centered Learning in Museums*, edited by S. G. Paris, 55-77. Mahwah: Lawrence Erlbaum Associates.

Guo, C. and M. Acar. 2005. "Understanding Collaboration among Nonprofit Organizations: Combining Resource Dependency, Institutional, and Network Perspectives." *Nonprofit and Voluntary Sector Quarterly* 34 (3):340-361.

Hein, G. E. 1998. The Significance of Museum Education. In *Learning in the Museum*, 1-13. New York: Routledge.

Henriksen, E. K., and M. Frøyland. 2000. "The contribution of museums to scientific literacy: views from audience and museum professionals." *Public Understanding of Science* 9: 393-415.

Hooper-Greenhill, E. 2007. *Museums and Education: Purpose, Pedagogy, Performance*. Oxon: Routledge.

ICOM. 2006. *ICOM Code of Ethics for Museums*. Paris: ICOM.

Janousek, I. 2000. "The 'Context Museum': Integrating Science and Culture." *Museum International* 52 (4): 21-24.

Koster, E. H. 1999. "In Search of Relevance: Science Centers as Innovators in the Evolution of Museums." *Daedalus* 128 (3): 277-296.

Lindqvist, K. 2012. "Museum Finances: Challenges Beyond Economic Crises." *Museum Management and Curatorship* 27 (1): 1-15.

Mairesse, F., and A. Desvallées. 2010. "Introduction." In *Key concepts of museology*, edited by André Desvallées and Francois Mairesse. Paris: Armand Colin.

Mairot, P. 1997. "A New Type of Museum Network in France: The Franche-Comté Museums of Local Culture and Techniques." *Museum International* 49 (2): 43-47.

McPherson, G. 2006. "Public Memories and Private Tastes: The Shifting Definitions of Museums and their Visitors in the UK." *Museum Management and Curatorship* 21 (1): 44-57.

NATHIST. 2013. *ICOM Code of Ethics for Natural History Museums*. ICOM.

Oppenheimer, F. 1968. "A Rationale for a Science Museum." *Curator: The Museum Journal* 11 (3): 206-209.

Osborne, J. and J. Dillon. 2008. *Science Education in Europe: Critical Reflections*. London: The Nuffield Foundation.

Pedretti, E. 2002. "T. Kuhn Meets T. Rex: Critical Conversations and New Directions in Science Centres and Science Museums." *Studies in Science Education* 37 (1): 1-41.

Plaza, B. 2007. "The Bilbao Effect." *Museum News* 86 (5): 13-15.

Proulx, Kelly E., Mark A. Hager, and Kimberly C. Klein. 2014. "Models of Collaboration Between Nonprofit Organizations." *International Journal of Productivity and Performance Management* 63 (6):746-765.

Quin, M. 1994. "Aims, Strengths and Weaknesses of the European Science Centre Movement." In *Towards the Museums of the Future. New European Perspectives*, edited by R. Miles and L. Zavala, 39-55. Oxon: Routledge.

Rennie, L. J., and G. F. Williams. 2006. "Communication about Science in a Traditional Museum: Visitors' and Staff's Perceptions." *Cultural Studies of Science Education* 1 (4): 791-820.

Sandell, R. 1998. "Museums as Agents of Social Inclusion." *Museum Management and Curatorship* 17 (4): 401-418.

Schweingruber, Lucy. 2013. "Ecsite Annual Conference. Evaluation and Recommendations." Ecsite, accessed October 19, 2016. http://www.ecsite.eu/sites/default/files/evaluation_report_ac2013.pdf

Simon, N. 2011. "Participatory Design and the Future Of Museums." In *Letting Go? Sharing Historical Authority in a User-Generated World*, edited by B. Adair, B. Foilene and L. Koloski, 18-33. Philadephia: The Pew Center for Arts & Heritage

University of Pittsburgh. 2016. "Primary Sources by Subject." Accessed October 17, 2016. http://pitt.libguides.com/primarysources

Weil, Stephen E. 1999. "From Being About Something to Being For Somebody: The Ongoing Transformation of the American Museum." *Daedalus* 128 (3):229-258.

Welsh, P. H. 2005. "Re-Configuring Museums." *Museum Management and Curatorship* 20 (2):103-130.